CHAPTER EIGHT

CLIMATE CHANGE, NORTHERN SUBSISTENCE AND LAND BASED ECONOMIES

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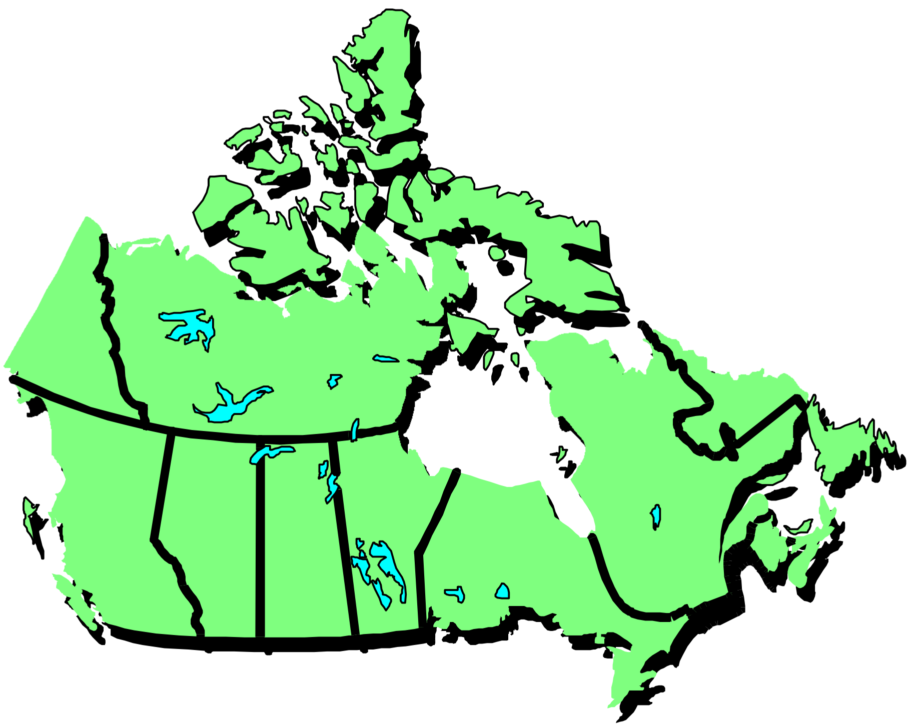

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

This discussion of climate change and northern subsistence societies starts from the premise that there is a distinct land-based subsistence and commercial economy in the Canadian North, that this economy has continued to be important, and that there are no short-term prospects of replacing the subsistence sector by the wage sector and industrial economy. Major issues and findings can be grouped into three categories: (1) *climate change may affect the distribution of animals and other resources on which the subsistence economy is based;* (2) *climate change may affect the use of traditional knowledge and local adaptations;* (3) *climate change may affect the health of northern populations through dietary dislocations and epidemiological changes.*

Research should be undertaken in three areas: (1) to link available biological/ecological information on the impacts climate change to local resource use and the northern economy; (2) to develop adaptive management strategies with emphasis on the resilience of social and ecological systems, and on flexibility to respond to uncertainty and largely unpredictable climate change; and (3) to study the issue of the health of northern populations relative to the potentially significant implications climate change has for the long-term availability of this country food. The analysis leads to the following recommendations:

1. More specifically targeted research is needed on impacts of climate change on resource availability.
2. More work should be encouraged to link available ecological information on resources to economic impacts.
3. Methodology needs to be developed to sort out the effects of climate change from the cumulative impacts of large-scale development, such as those of hydroelectric projects.
4. What are the limits to adaptability in northern subsistence economies?
5. A better understanding of non-linear, discontinuous (non-gradual), unexpected effects of climate change on northern regions is needed.
6. Develop adaptive management strategies which rely on feedback learning and on policies designed as experiments from which resource managers can learn.
7. Develop policies to implement ways in which flexibility is built into resource management systems and institutions.
8. Develop policies to implement ways in which rapid response can be initiated more effectively, as in the case of extreme events and emergencies.
9. Build flexibility into management systems and institutions by delegating more responsibility to the local level.
10. Recognize the importance of local sources of protein for the overall well-being of northern populations.
11. Recognize that the mixed economy of northern aboriginal communities is not a transition stage but an adaptive economic organization that enhances self-reliance. A full switch into a wage economy is, in any case, *not* an option.

12. Develop policies that encourage self-reliance while providing wage income opportunities for northern peoples.
13. More work is needed to draw together findings relating the consumption of country foods to various indices of health.
14. Little seems to be available on epidemiology of climate change for the north; this area needs more research.
15. Develop methodology to estimate the costs of increased dependence and the costs of facilitating potential adaptations.

ISSUE DEFINITION AND SCOPE

Northern indigenous peoples, already one of the more vulnerable segments of Canadian society, would be affected by ecosystem shifts that may be outside the limits of historical experience. If these shifts occur at a rapid pace, there may be difficulties in adapting. - *From the submission of the Canadian Global Change Program to Canadian energy and environment ministers.*

The focus of this paper is on the land-based economy of Canada's northern indigenous peoples. The subject cuts across regions, from Labrador across the Northern parts of Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, to the Northwest Territories and Yukon. It also cuts across resource types: wildlife, fisheries, forest resources and water. The area covered is vast, although indigenous populations in the Canadian North are small and no one lives entirely off the land. The issues discussed here may be applicable to some non-aboriginal populations elsewhere in Canada as well, especially to rural populations in the mid-north. However, there have been no studies to establish the degree of reliance of non-indigenous groups on a land-based economy.

In the case of indigenous communities, numerous studies have been carried out in all regions of the Canadian North since the 1970s on aboriginal land use, wildlife harvesting, and socio-economic change. These studies have been largely related to aboriginal land claims and to the environmental assessment of development projects. These studies have established that (1) the subsistence sector is worth about $15,000 per household per year in the Arctic and about half that in the Subarctic; (2) the subsistence economy often comprises one-quarter to one-half of the *total* local economy; (3) the subsistence economy is *not* disappearing and may even be becoming stronger; and (4) there are no short-term or medium-term prospects that the subsistence sector can be replaced by the wage sector and industrial economy—the jobs do not exist nor are they likely to be created (Berkes and Fast, 1996). As the Mackenzie Delta Beaufort Sea Regional Land Use Planning Commission (1988) concluded, "apart from the oil and gas potential, there are no easy opportunities for increased economic activity either through entrepreneurial activity or jobs". Tourism was identified as a potential source of jobs, but that also requires a local population which is active on and knowledgeable about the land.

Very little is known about the possible impacts climate change might have on the northern economy. On the one hand, environmental change is integral to the daily lives of northern peoples, and a capacity to adapt to change is part of their livelihood systems. On the other hand, extreme events and unusual fluctuations create safety hazards as well as adaptation problems, and little is known about their cultural, social and economic limits to adaptability. A case in point is the disappearance of Norse colonies in Greenland. Detailed archaeological work has revealed that cooler periods occurred from 1308-18, 1324-29, 1343-62, and 1380-84. The cold spell of 1343 corresponds with the abandonment of the Western settlement. A key factor seems to have been a reduced capacity among the Norse people to produce and store fodder for their farm animals. Historically they had been able to store enough fodder for one, and at most, two years. A cold spell that prevented fodder production for two years represented the limit of the resilience of the Norse farming economy and their livelihood system. Unable or unwilling to adapt to a marine mammal and fish diet like their Greenland Inuit neighbours, the Norse died off after eating the last of their starving animals (Pringle, 1997).

In a similar vein, the impact of climate change on Canada's contemporary northern peoples may be evaluated with special attention to limits of adaptability and resilience of northern economies. The literature emphasizes the importance of the adaptations of arctic and subarctic peoples to cope with fluctuations in resource availability. But the literature also points out that non-climate related changes have impacted these groups more than have climate changes in the last few decades (Langdon, 1995; Wenzel, 1995). In recent historical times, northern populations have been impacted by epidemics, acculturation and social and economic change, including for example the collapse of fur markets (Wenzel, 1995). By comparison, the impact of recent climate change on the welfare of northern peoples has been negligible. Based on studies in Aklavik and Fort Liard, Newton (1994) concludes that the sustainability of northern communities is impacted more by direct human-induced perturbations than slow changes to the natural environment; nevertheless, potential increases in the severity of extreme climatic events could influence losses. There is good evidence that northern peoples notice and respond more to *extreme events* than to changes in *mean conditions* (Aharonian, 1994), and that *unpredictable* changes are more important and potentially damaging than predictable extreme events (Berkes, 1988). The relevant body of theory that bears on these issues concerns the resilience of ecological and social systems and adaptive management (Holling,1986; Berkes and Folke, 1997).

The relationship between climate change and northern subsistence economies can be analyzed around three major issues, all related to adaptation, flexibility, resilience and unpredictable change:

1. Climate change may affect in unpredictable ways the distribution of animals and other resources on which the land-based economy depends;
2. Climate change may affect the use of traditional knowledge and local adaptations; and
3. Climate change may affect the health of northern populations through dietary dislocations and epidemiological changes.

HOW CLIMATE CHANGE MAY AFFECT NORTHERN SUBSISTENCE AND LAND-BASED ECONOMIES

The northern economy is comprised of three sectors: the wage sector, transfer payments, and subsistence harvesting. The largest source of cash in the north has for the past forty years been government expenditures. Other important sources of cash include the wild fur industry, tourism, and the sale of native handicrafts. Although there is a divergence of opinion concerning the accuracy of these figures, according to various studies since the 1970s, the northern subsistence or land-based sector is worth about $15,000 per household per year in the Arctic and about half that in the Subarctic (Table 8.1). A significant part of wage and transfer income goes into the production of country food for subsistence. This land-based economy is typically one-quarter to one-half of the *total* local economy (the rest being the wage and transfer sectors) (Table 8.2). The compilation of data from several dozen studies across the Hudson Bay Bioregion has produced a substantial body of evidence documenting the vigor with which subsistence activities continue to be practiced across Canada's Arctic and Subarctic regions. Despite the changing world in which subsistence societies live, and despite greater cash flows than in earlier times, there has not been a significant decline in subsistence activities in the Arctic and Subarctic.

Table 8.1 Imputed value of subsistence country meat

					Value per household per year	
Region	**Year**	**Potential edible weight (kg)**	**Imputed value ($)**	**No. Of households**	**Current $ (year of study)**	**Constant $ (1991)**
Keewatin	1981-2	829 440	7 879 680	665	11 849	17 892
	1982-3	793 003	7 533 529	685	10 998	15 727
	1984-5	895 298	8 505 331	705	12 064	15 925
Mushkegowuk	1990	686 713	7 846 155	1 116	7 031	7 453
Pinehouse	1983-4	84 455	451 307	98	4 605	6 290
Wemindiji	1975-6	67 636	372 000	117	3 180	8 459
	1976-7	79 272	436 000	121	3 603	8 863
Northern Manitoba	1983-4	355 529	1 462 931	1 238	1 167	1 594

Full references and explanatory notes may be found in Berkes and Fast, 1996.

Table 8.2 The land-based sector in the overall economy

	Total cash economy per year			Imputed value of Native traditional activities		
Region	**Year**	**Current $ (year of study)**	**Constant $ (1991)**	**Current $ |(year of study)**	**Constant $ (1991)**	**Cash economy to traditional economy**
Sanikiluaq	1984	2 155 000	2 952 350	2 946 515	4 036 726	1:1.37
Mushkegowuk	1990	25 370 880	26 893 133	8 372 400	8 874 744	1:0.33
Northern Manitoba	1985	178 827 600	236 052 430	22 367 500	29 525 100	1:0.13
Waswanipi	1968-70	251 315	774 050	209 665	645 768	1:0.83
	1982	1 814 451	2 739 821	684 667	1 033 847	1:0.38
Wemindji	1975-6	625,000	1 687 500	531 000	1 433 700	1:0.85
	1977-8	1 184 000	2 960 000	732 000	1 830 000	1:0.62
Pinehouse	1983-4	2 101 289	2 878 766	1 135 281	1 555 335	1:0.54

Full references and explanatory notes may be found in Berkes and Fast, 1996.

Climate change is likely to have dramatic impacts on these subsistence economies. Though some scientists are predicting cooling, most are anticipating a warming trend. Some are predicting a gradual period of transition, others a dramatic reversal. The study of ice cores supports the notion of dramatic climate change for the warmer; Beaulieu (1997) argues that natural and anthropogenic conditions are pushing the climate to the earth's limits of tolerance and will force it to 'flip' into very different conditions. Climate change, if it comes, is expected to have its greatest impact in arctic and sub-arctic latitudes (Roots, 1996). There is already evidence to suggest that change will not be uniform across the region. The western Arctic, for example, and particularly the Mackenzie Delta area, is expected to experience more seasonal variability and a more complex pattern of change than the eastern Arctic (Maxwell, 1987). Any of the projected scenarios, however, will directly and indirectly affect the health of the resources on which the subsistence economy is based, and the environment in which the harvesting occurs.

Climate Change May Affect the Distribution Of Animals And Other Resources On Which Northern Subsistence And Land-Based Economies Are Based.

Projected Effects of a Warmer Climate on the Subsistence Land Base

The climate warming scenario projected by computer models as well as by analysis of historical climate patterns suggests a warming in the Arctic of 8°C to 10°C in winter and 1°C to 2°C in summer. These predictions anticipate increased storm activity, moisture and windiness, with an average increase in precipitation of 20 to 30 percent. The number of days lakes will be ice-covered is expected to decline by 30 to 35 days according to one estimate (Maxwell, 1987) and by as much as 120 days in the fall and another 15 days in spring (DOE, 1991). Snow-cover days are projected to be reduced by 30, with a concomitant possible increase in spring run-off and flooding. Summers may become ice-free, and winter ice may become thinner (Maxwell, 1987).

Most primary productivity in the Arctic Ocean is the work of microscopic algae which use the bottom surface of the ice as initial habitat and later extend to the water surface. These algae are most active at the ice edge during the short time period during which the ice melts. Since the ice edge moves north as it melts, the season of highest growth in any area is limited to a few weeks, and in total covers an area of 5 to 10° latitude. This same small area attracts the larger animals who rely on these sources for food (PAME, no date). Plankton are either plants (phytoplankton) or animals (zooplankton). The latter includes a group called icthyoplankton—the drifting eggs and larvae of many fish species. Increases in ambient UVB could stress these species and cause their disappearance or adaptation to a different, potentially less nutritional, form (Diffey, 1991).

Under conditions of climate warming, multi-year ice and large areas of permafrost are expected to disappear. As the treeline moves northward by about 200 to 300 kilometres in response to warmer temperatures, and the tundra moves back to cover only the archipelago, the variety and volume of vegetation will increase in the region (Harris, 1987; Bregha, 1987). Such a movement of the tree-line will in turn have implications for the amount of snow cover. Increased snow-fall would result in later snow-melt which in turn would delay the flowering of vegetation which already has a very short period of productivity (Scott and Rouse, 1995).

Another effect of heavier snowfalls would be wetter and cooler springs and a shortening of the annual frost-free period. "Any change that promotes higher winter snowfall will have a pronounced effect on vegetation communities even if summer precipitation and temperature remain unchanged" (Scott and Rouse, 1995). Thawing of the permafrost would also result in 'thaw lakes' and subsidence on the land, disrupting natural drainage patterns, damaging forests and making travel much more difficult (Harris, 1987). In sum, such degradation of the permafrost will have serious ramifications for existing ecosystems and wildlife habitat (Canadian Climate Program Board, 1991), and so for the wildlife on which subsistence harvesting depends.

Forests, Wildlife and Waterfowl

One-third of Canada's land area is boreal forest (Jackson, 1992). Some researchers predict the northward shift of the treeline at a rate of 100 to 250 km per decade (DOE 1991), or 25 times faster than under normal conditions. Pruitt (1993) and Jackson (1992), however, anticipate the loss of large areas of forest, particularly in the southwestern half of the taiga—"the northern (or boreal) coniferous forest"—first to insect invasions of budworms, sawflies and bark beetles, and then to massive forest fires. The northward movement of the forest, he suggests, will not occur until soil conditions become compatible with forest growth (Pruitt, 1993). Some researchers predict fewer forest fires overall, under conditions of climate warming, while recognizing there might also be periods of drought in the southeastern boreal forest which could lead to an increase in forest fires (Bergeron and Flannigan, 1995; Jackson, 1992).

Terrestrial, aquatic and marine animals in the Arctic and subarctic live in a marginally supportive physical environment at the best of times, and small changes in conditions can have major impacts on their health and survival. Roots (1996) concludes that the conditions of rapid warming suggested by climate models will lead to significant decreases in the productivity of both northern forests and to a reduction in the number of large animals in the forest and on the tundra: "During episodes of temperature change or other climate change, it is the animals and plants with short life cycles that can adapt most readily to take advantage of changed conditions. Thus, viruses, soil bacteria, parasites, insects and annual plants will respond more rapidly than long-lived plants such as lichens or sedge grasses, or long-lived animals like whitefish, caribou, wolves or geese". The literature provides historical evidence that some animal population fluctuations can be correlated to temperature shifts. As the climate in Canada warmed during the 1920s to the 1940s, for example, lynx populations almost became extinct, partly because temperatures above –25°C create softer snow crusts and make travel impossible for lynx. As temperatures cooled over the next thirty years these populations recovered dramatically (Scott and Craine, 1993).

Winter caribou ranges will be reduced as palsas in the Hudson Bay Lowlands collapse over thawing permafrost. Both barren-ground caribou and woodland caribou will experience reduced habitat, due to fires and thicker, harder snow conditions. The movements of land animals—including caribou, moose, arctic fox and wolves—will be constrained by longer periods of open water over more extensive areas. Polar bear, ringed and bearded seal populations will likely decline as the extent of sea ice needed for habitat declines in extent. White-tailed deer, on the other hand, will be expected to increase their range northward, leading to an increase in wolf and coyote populations. Mink, otter, and likely beaver populations will decline, writes Pruitt (1993), in response to drier conditions which reduce their habitat and fragment ranges. Snowshoe hare and white-tailed jackrabbit and ground squirrel populations will increase, though tree squirrels will decline in number as forests are reduced. Thawing permafrost will impose major alterations on prime waterfowl and shorebird breeding and molting grounds along the coasts, resulting in sea level rises and saltwater intrusion (DOE, 1991). Maarouf and Boyd (1997) consider the northward shift of the treeline, and the destabilization of permafrost and vegetation in geese feeding areas to be detrimental to goose populations.

Long-term ecological studies at La Persouse Bay, Northern Manitoba, provide a striking example of how climate change can produce unpredictable effects through the loss of ecological resilience. Cold episodes and bad weather in spring has resulted in migrating lesser snow geese to remain longer in the Bay. Since the Bay already has a resident breeding population of lesser snow geese, the increased grubbing pressure on the roots and rhizomes of saltwater marsh graminoids results in the destruction of saltmarsh swards before the onset of above-ground growth. With the loss of the insulating mat of vegetation, the sediment surface becomes hypersaline as a result of increased evaporation, further reducing plant growth. This positive feedback relationship eventually exceeds the ability of the system to absorb perturbation and still maintain its ecological integrity, i.e., its resilience (Holling, 1986). The marsh, having lost its ecological resilience, becomes a desert, flipping into a different equilibrium, one that no longer supports geese (Srivastava and Jeffries, 1996).

Fish and Marine Mammals

Fish and marine mammals comprise an important component of the subsistence economy, accounting for as much as 20% of the subsistence harvest of the West Main Cree in Northern Ontario (Fast, 1996 after Berkes *et al.*, 1994). Climate change is expected to affect fish populations through changes in water temperature and circulation patterns (Jackson, 1992). The rate of metabolism of the fish and demand for food will increase with warmer temperatures. Under conditions of warmer temperatures spawning and hatching will occur earlier, while the incidence of bacterial disease is expected to increase. Other influencing factors include food availability and competition for these resources (Lin and Regier, 1995). Though the effects of climate change on fish populations in Northern Canada have not been the subject of much study (Reist, 1994; Jackson, 1992), it is known that their capacity to adapt to changed environments is very much species specific. Under conditions of rapid change fish will either move northwards, disappear from present ranges, or become genetically altered (Lehtonen, 1996). Reist (1994) has also noted that the effects of various events taken together can be cumulative, with the actual impact on fish being greater than the events taken singly would suggest. Some examples of such ‘various events’ include climate change, resource exploitation, contamination and changes in local habitat.

Coldwater fish species generally, and arctic char populations in particular, are expected to suffer a decline caused by decreases in the extent of summer habitat and reductions in oxygen concentrations. Their optimum temperature range for growth is 5 to 16°C, with lethal temperatures occurring between 22 and 27°C (Lehtonen, 1996). Arctic cisco, on the other hand, “one of the most abundant of the anadromous fishes and an important component of commercial and native subsistence fisheries" in the Beaufort Sea, seem to have a preference for warmer temperatures in test conditions, and can also tolerate high salinities typical of marine environments (Fechhelm *et al*., 1993).

In sub-arctic regions it is anticipated that significant changes in fish species will occur in waters presently populated with lake whitefish, walleye, northern pike and lake trout. The introduction of new species will have mixed effects ranging from negative to benign to positive. It has been suggested, however, that "the future prospect of extensive regional modifications of freshwater species distributions as a result of climate change should be greeted with alarm" (Minns and Moore, 1995; DOE, 1991). Implications for the future of subsistence and commercial arctic and sub-arctic fisheries are potential serious.

Under conditions of warming, marine mammals such as beluga, bowhead whales, harbour and harp seals and walrus are expected to increase in numbers, and to occupy a larger range as pack ice retreats (DOE, 1991). These increases in number may have positive effects on the Arctic subsistence economy and life-style,

Economic Impacts

Melting glaciers coupled with thermal expansion of the oceans are expected to raise mean sea levels 0.5 m or more, particularly in the Beaufort Sea region (Canadian Climate Program Board, 1991; DOE, 1991). Such changes in sea level are expected to have devastating effects on the Arctic's coastal settlements, and costly measures will be needed to protect them from flood damage, if indeed they can even be protected.

An increase in activity in the permafrost would have mixed implications for the both the cash and the subsistence economies. Though onshore oil and gas development would become more expensive with softening permafrost, offshore hydrocarbon developments would benefit from more moderate conditions, and marine transportation would become viable for an additional six to eight weeks annually. A reduction in permafrost would also facilitate less costly mining operations (Maxwell, 1987), and the development of presently known reserves of oil, natural gas, lead, zinc and iron ore might become economically viable (Bregha, 1987). Benefits could be expected to accrue to the tourism, recreation and marine transport sectors (DOE, 1991). In the Western Arctic, which is drier and rockier than the eastern Arctic, however, rapid increases in the active layer of permafrost would exceed existing structural tolerances for movement (Harris, 1987). Similarly, winter and all-weather roads would become unstable and so would be available for shorter periods each year. Accessibility to fish and wildlife habitats would be affected, thereby altering subsistence and commercial harvesting patterns (DOE, 1991).

Influences of a Colder Climate

Ice cores can provide evidence of climate for the past 100 000 years, and some studies of arctic ice cores have suggested that climate trends are not toward warming, but rather a 'return' to the ice age (Koerner, 1987). The majority view is for a warming trend, within which some areas such as the Labrador coast, may be getting cooler (Cohen *et al*., 1994). The view that cooling is more likely than warming is espoused by Ball, a historical climatologist, who argues that cooling will be "much more devastating" for all Canadians, including northern populations, than would warming (pers. com., 1997). Historical records provide an indication of what the effects of cooling might be on vegetation and wildlife.

During the last major cooling of the Arctic around 1500 BC to 1700 AD the tree-line retreated as a consequence of massive fires in the dying forests (McGhee, 1987). Even monthly mean temperature changes of as little as 1°C during the warmest or coldest months of the year have been shown to alter the extent and type of vegetation found in these regions (Ball, 1986). It is conjectured that during that period of cooling the caribou for example, were forced to alter their migration routes in search of vegetation (McGhee, 1987). As temperatures dropped hunters had increasing difficulty securing food, as the caribou had moved inland, and whales could no longer summer in the estuaries where they had previously been hunted. The Inuit are thought to have adapted by hunting the growing number of ringed seal which became more plentiful as the sea ice extended (McGhee, 1987). The Inuit also began spending summers inland, relying on fish and hunting the caribou they found there. In this way they adapted to the suddenly altered and regionally variable conditions which occurred during the Little Ice Age (McGhee, 1987).

If the climate were to become cooler the current area of permafrost would be extended southward and some ground heaving could be expected. Overall the impacts on infrastructure should not be extensive, while the effects on winter roads would be such that they could be used for longer periods each year. Finding water supplies, however, could become more problematic, and might require the modification of systems used to transport water in order to keep them from freezing (Harris, 1987).

Communities around the Hudson Bay have experienced some cooling effects over the past several decades, thought to be caused by the melting of Greenland's ice cap and the cooling trend off Labrador. The changes which have been observed, however, are instructive in considering what the impacts of a cooling climate might be on the subsistence environment: shorter springs; less eel grass which is used by migrating geese as food; cooler temperatures; rapid and early passage of fall seasons; increased snowfall (resulting in fewer geese stopping over to feed along the coastal areas during their fall migration); a shift in wind direction from the north in spring and preventing the geese from landing in large flocks; a haze that seems to be blocking the sun's warmth; spring tides failing to prevent polynyas freezing over (Arragutainaq *et al.*,1995).

Climate Change May Affect the Use of Traditional Knowledge and Local Adaptations

Traditional ecological knowledge (TEK) represents experience acquired over thousands of years of direct contact with the environment. Berkes (1993) proposed a working definition of TEK as "a cumulative body of knowledge and beliefs handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment". The term is, by necessity, ambiguous since the word 'traditional' itself is ambiguous. It usually refers to cultural continuity transmitted as conventions of behaviour and practice derived from historical experience. However, societies change through time, constantly adopting new practices and technologies, making it difficult to define just what is 'traditional'.

Because of this, some scholars avoid the term ‘traditional’ and prefer ‘indigenous knowledge’, which helps avoid the debate about tradition, and explicitly puts the emphasis on indigenous people.

‘Ecological knowledge’ poses definitional problems of its own. If ecology is defined narrowly as a branch of biology in the domain of Western science, then strictly speaking, there can be no TEK; most traditional peoples are not scientists. The alternative is to define ecological knowledge broadly to refer to the knowledge, however acquired, of relationships of living beings with one another and with their environment. In this regard, ‘ecological knowledge’, is not the term of choice for many indigenous peoples themselves. Many native peoples of the Canadian North refer to their ‘knowledge of the land’, rather than to ecological knowledge. In this sense, however, ‘land’ is more than the physical landscape; it includes the living environment. In recent years, many kinds of indigenous environmental knowledge and their uses, including the use of TEK for climate change research, have been acknowledged, but the relationship of TEK to science remains controversial (Berkes and Henley, 1997).

Hunter/fisher/trappers depend on detailed local knowledge of animal distributions and behaviour, snowfall patterns, and timing of freezeup and breakup. One of the earliest studies of climate change and traditional knowledge was carried out by Spink (1969) who showed the value of local Inuit knowledge in corroborating evidence for isostatic rebound. Cruikshank (1984) noted that traditional knowledge could be applied to historical research on climate, geophysical research and paleontology. Much of the Lutsel K’e Dene environmental knowledge is concerned with snow and ice, and hunters pay particular attention to quantity, quality and occurrence of snow cover and snow melt patterns, and freeze-up and break-up patterns and timing (Bielawski, 1994). A linguistic study by Basso (1972) revealed 13 categories of freshwater ice, based 20 compositional features, among the Dene of Fort Norman. Such knowledge is not static; it is often updated and modified. But nevertheless, climate change can play havoc with the use of such knowledge by making locational knowledge unreliable. A case in point is the change of ice break-up and freeze-up patterns in the estuary of the La Grande River (in this case due to hydro development), and the hardship this caused for the Chisasibi Cree trying to travel between the village and their hunting grounds (Berkes, 1988). Particularly distressing for the hunters was the fact that ice colour could no longer be used reliably as a cue to gauge ice thickness (but tapping the ice still provided a reasonably accurate indication).

The real experts of sea ice are the Inuit. This is perhaps not surprising considering that many Inuit traditionally lived and hunted on the sea ice. A compilation by Riewe (1991) shows that at least one-third of the total community hunting area is marine (i.e., open-water in the short summer but ice most of the year) in about half the Inuit communities in the NWT. Inuit knowledge of snow and ice is legendary (although sometimes exaggerated), and snow terminology of aboriginal peoples have been adopted by some northern ecologists because of the precision of this terminology, as illustrated in Table 8.3 summarized from Pruitt (1984).

Findings from two major traditional knowledge studies, in the Hudson Bay area and in the Northern Basins Study (N. Alberta/NWT) indicate local evidence for climate change, confounded by cumulative impacts of development. In the case of the former, a number of changes were noted

Table 8.3 Some specialized snow terminology

Term	Source	English equivalent
anmana	Inuit	space formed between drift and obstruction causing it
api	Inuit	snow on ground, forest
ciegar	Sami	‘feeding trench’ through undisturbed api
cuok’ki	Sami	layer of solid ice next to the soil
fies’ki	Sami	‘yard crater’ of thin, hard and dense snow caused by reindeer digging
kaioglaq	Inuit	large hard sculpturings resulting from erosion of kalutoganiq
kalutoganiq	Inuit	arrowhead-shaped drift on top of upsik; moves downwind
pukak	Inuit	fragile, columnar base layer of api
qali	Inuit	snow on trees
qamaniq	Inuit	bowl-shaped depression in api under coniferous tree
sandjas	Sami	fragile, columnar basal layer of api (=pukak)
suov’dnji	Sami	‘feeding crater’ excavated in the api
upsik	Inuit	wind-hardened tundra snow cover

Adapted and condensed from Pruitt 1984. The Inuit terms are from the Kovakmuit. Sami - Lappish from Northern Scandinavia.

(Bill *et al*., 1996). The local people noted that there were more fires, especially forest fires, and they were more intensive today. Hunters thought that the fires were related to loss of caribou habitat. Land was becoming drier and flow patterns of rivers had changed. Reduced water levels in the Peace-Athabasca Delta, hunters thought, was related to reductions of the populations of waterfowl, muskrat and many species of fish. These last two changes may have been partly related to hydroelectric development (W.C. Bennett dam in BC). More difficult to interpret was the reduction in song-birds (problems with overwintering habitat?). Reduction in the ‘prairie’ or sedge meadow habitat was related to a decrease of bison numbers. Increase in willow and forest encroachment in the Peace-Athabasca Delta was related to increase of moose. More directly on climate change, local people observed that it was more common today to experience snowfalls prior to sub-freezing temperatures (Bill *et al*., 1996).

In the case of the Hudson Bay study, representatives of six regions of the area, both Cree and Inuit, have provided detailed accounts of changes they have observed over the years. Many of these changes were suspected to be related to the cumulative impacts of hydroelectric development projects in Quebec, Ontario and Manitoba, and in fact the study was spearheaded by the Inuit community of Sanikiluaq, located on Belcher Islands, as part of their response to the Grande-Baleine environmental assessment. Some of the observed changes, change in goose migratory patterns from the James Bay coast inland, may well be related to hydro development (string of reservoirs attracting migratory geese). Other observed changes are difficult to relate to hydro effects. For example, in the area of Belcher Islands, Inuit hunters indicated that some 35 polynias present in the 1950s were reduced to 13 in 1960-70, and to three in the 1990s (Arrangutainaq *et al*., 1995).

In Southampton Island local people reported that snow has started coming before freshwater freezes, creating a different kind of lake ice. Whale Cove reported that snowfall had increased but that it melted earlier than it did in the past. Chesterfield Inlet, Southampton Island and Arviat all reported increasingly more erratic weather, such as snow melting by May, but blizzards occurring as late as June. A number of Hudson Bay communities reported that the main offshore currents and tidal currents have been weakening through the 1980s. Different communities were reporting changes in potential vector species. Whale Cove reported black flies as a new arrival, whereas Repulse Bay indicated that mosquitoes have declined (McDonald *et al*., 1995).

Climate Change May Affect the Health of Northern populations through Dietary Dislocations and Epidemiological Changes

An inability to hunt and fish no longer results in starvation, but it has been contributing to dietary problems and medical costs through elevated levels of cardiovascular disorders, diabetes and vitamin-deficiency disorders. A review of aboriginal wildlife and fish harvest studies shows that most of the harvesting in the Canadian Arctic fall in the range of 200 kg to 400 kg of potential food per person per year, and in the Subarctic 50 to 150 kg (Berkes and Fast, 1996). Estimated on the basis of the number of animals taken multiplied by the average edible weight per animal, these figures indicate the potentially edible meat per capita per year, minus wastage and meat consumed by dogs.

These harvests of wildlife represent high values compared to the meat and fish eaten by Canadians in the south. Furthermore, wild meat is very healthy food, and if consumed fresh provides all the dietary requirements for vitamins as well as minerals (Schaefer and Steckle, 1980). A harvest of some 300 kg of meat per year for every man, woman and child in the Arctic corresponds to a potentially available food weight of about 1.2 kg meat, and 300 g of protein per adult-equivalent per day (explanations and conversions may be found in Berkes and Fast, 1996). This protein value of 300 g may be compared with Nutrition Canada's minimum adequate standard of 60 g protein per day for a 70 kg person.

"Based on 24-hour diet recalls in 1992 and 1993, country food provided an average of 42 grams of protein for Inuit women under 45 in northern Quebec. The average was higher for men under 45 (43 g), and for those over 45 (54 g for women, 88 g for men). In six other Inuit community surveys, women under 45 obtained an average of between 50 and 80 g of protein from country food" (Hill, pers. com., 1997). Figures based on consumption studies will be lower since some of the potential food weight available from harvests will be wasted.

Climate change and general socio-economic change in the North, however, are not the only threats to local food sources, as there have been problems with arctic food chain contamination (Cameron and Weiss, 1993), through the long-range atmospheric transport of contaminants to the Arctic. PCBs and other organic contaminants also occur at concentrations that are a cause for concern in the arctic food web, especially in marine mammals. Among the heavy metals, mercury has received attention as the one most likely to have implications for human health; cadmium and possibly lead can also be a problem (Muir *et al*., 1992). The PCBs in the Inuit diet are especially important and some Inuit women in the Hudson Bay area are known have PCB concentrations in breast milk which are five times higher than those of southern Canadians (Dewailly *et al*., 1989). Overall there seems to be a seven-fold difference in total PCB for southern vs. northern human milk (Dewailly *et al*., 1993).These contaminants problems are not new; they have interfered with aboriginal resource harvesting since the mid-1970s (Berkes, 1980). It is conjectured that climate change may alter the pattern of transport of the various contaminants to the northern regions.

"Increased temperatures could result in an increased degree of revolatilization of contaminants presently stored in soils and oceans, implying that a greater quantity may become available for atmospheric transport and that the cycling of contaminants through the global ecosystem may change. Whether or not this would lead to increased deposition in the Arctic is unclear as increasing temperatures would likely alter precipitation regimes and therefore 'wash-out' of contaminants from the atmosphere" (Han, pers. com., 1997).

During the 1950s and 1960s, northern aboriginal peoples were settled into year-round villages. This settlement resulted in major changes in activity patterns (less physical activity), diet (less fresh meat and more fat, sugar and processed foods), demographics (more babies), and social and cultural values. This paper focuses mainly on diet-related problems as climate change may interfere with wildlife harvests. Human consumption of country foods in the North is high on a per capita basis, with average annual per capita consumption of country foods in Keewatin, Kitikmeot and Baffin Island regions estimated at 267 kg—more than twice the national average annual meat and fish consumption of southerners (DOE, 1991; Wein and Wein, 1995).

A survey of the Inuit in northern Quebec indicated that country food continues to be a very important part of the diet of adults over 45, and that those under 45 consume significantly more store foods. The survey also found that those under 45 also consumed significantly more foods with little nutritional value than did those over 45 (Lawn and Langer, 1994). For women under 45 the most important country foods, in order of priority were: caribou; char; geese; ducks; ptarmigan; dried caribou and beluga skin. The researchers concluded that the trend away from country food by younger people could lead to an even lower nutritional status and a concomitant increase in the incidence of 'chronic lifestyle diseases' (Lawn and Langer, 1994). Both cultural survival and health were linked to continued availability of country foods. It is known that these country foods contain chlorinated organic compounds, thought to be the biggest threat to human health because of their "persistence in the environment, high biomagnification, generally high inherent toxicity, widespread use, and high tendency to be stored in the fatty tissues of animals" (DOE, 1991).

This issue has not been well studied, but concern is primarily related to developing fetus and breast-fed babies. Lichens trap radioactive fallout, and since lichens are the primary source of food for caribou there is some concern about the health of people eating primarily caribou, though risks are believed to be very low. Consumption of country foods also exposes individuals to unsafe levels of methylmercury in fish (DOE, 1991). The safety of the country foods being eaten was raised as a major concern at every community meeting as part of a study of food consumption, nutrition and health of aboriginal people conducted in Pond Inlet, Repulse Bay, Nain, Fort Severn, Davis Inlet, Arctic Bay, Gjoa Haven and Coral Harbour. Food security was a major concern as the result of low income levels, high food costs, high unemployment, inadequate social assistance, reduced access to country food and concern over the safety of country food (Lawn and Langner, 1994).

In this respect a major dietary problem is that as the consumption of fresh meat (i.e., not frozen or preserved) in the diet has declined, the nutrients formerly provided by this diet (Berkes and Farkas, 1978; Schaefer and Steckle, 1980) are not replaced by new foods. The pursuit of subsistence harvesting demands a high level of physical fitness. As members of subsistence societies fall prey to modern diseases they are less able to hunt for wildlife and so contribute to their family’s welfare.

A warmer climate would result in melting permafrost and subsequently to thawing of wastes. The now-active waste bacteria would become able to move through the thawed soil, thereby greatly increasing the possibility of contaminating water resources (Harris, 1987). The increase of ultraviolet-B radiation caused by thinning of the ozone layer in the arctic stratosphere is a real threat to human and animal health as well as to productivity of terrestrial and marine vegetation, but impacts are presently minimized because little human skin is exposed to the sun when levels are highest in March and April. Similarly, most vegetation is still under snow at that time. Those traveling across the snow, however, including humans, dogs, wolves, musk oxen, Peary caribou, and birds such as the snowy owl, raven and ptarmigan could be at risk of eye damage (Roots, 1996).

It has been observed that latent conditions can become acute or chronic when individuals are exposed to stress, and there is some concern that the increased incidence of tuberculosis among Canada’s native population could be such a response. Also, evidence of poor nutritional status has implications for the healthy development of fetus and children. Warmer climates would extend the suitable habitat of disease vectors such as mosquitoes, potentially spreading malaria for example. As animal habitats change the insects that live on them also change their habitat. Even the further encroachment of farming on marginal lands has potential implications for disease vectors (Hackett pers. com., 1997).

ADAPTATION OPTIONS

There is much evidence that aboriginal societies will be able to adapt to minor climate fluctuations—as they have done for centuries—whether they be of short or long term duration. For example, despite the loss of their resource base caused by extensive hydroelectric development, and subsequent difficulties associated with subsistence land use activities today, members of York Factory First Nation in northern Manitoba are still very much aware of the presence of wildlife in the waters and lands surrounding their reserve, as well as in their traditional hunting area around York Factory and along the Hudson Bay coast almost two hundred miles away. One hunter tracked in a study by Fast (1996), for example has adapted to changes in the flow of the Nelson River and is once again able to travel to York Factory by way of this river all summer long. One year he made the trip eleven times. He and several others fly to Gillam from York Landing. From there they travel the 28 miles to the Limestone Generating Station where he leaves his 18 foot 35 horsepower outboard aluminum canoe. Water is released daily at 8:00 a.m. at Long Spruce, and by ll:00 a.m. the water at the Limestone Generating Station is high enough to allow them to launch their canoes and paddle to Gillam Island. This stretch of the journey takes eight hours to complete. When they reach Gillam Island they wait for the Hudson Bay tide, which comes in as far as the island, to carry them to York Factory. This part of the trip takes about two hours, and they arrive at York Factory about 2:00 a.m., a day and a half after they started. Along the way, and once at York Factory, they hunt. They again 'ride the dam tide' to return home (Fast, 1996).

This is one illustration of the adaptability of subsistence societies in the face of environmental change. The types of changes anticipated to accompany climate change as described, however, are likely to severely challenge the capacity to adapt of many subsistence societies. The effects are likely to be wide-spread, with regional variations, and attempts to modify or prevent events/effects for vast northern regions are not likely to be viable once the impacts begin to be felt. The transition to settlement life over the last forty years has reduced, though not eliminated, their options for traveling to new areas in response to animal migrations. Loss of waterfowl and fish populations will have serious implications for the subsistence economy because these resources will not likely be replaced by other wild food sources. Even an increase in government financial government support, were it to be provided, would not compensate for the losses in overall well-being. A move to urban centres, should the subsistence economy collapse, would in all likelihood not enhance the overall well-being of these people either.

RESEARCH AND MONITORING NEEDS

We focus on three areas of research and monitoring needs: (1) linking the available biological and ecological information on the impacts climate change to local resource use and the northern economy; (2) developing adaptive management strategies with emphasis on the resilience of social and ecological systems, and on flexibility to respond to uncertainty and largely unpredictable climate change; and (3) studying the issue of the health of northern populations relative to the potentially significant implications of climate change for the long-term availability of this country food.

Regarding the first point, research is needed to acquire biological information on the potential impacts of climate change on resource use. But perhaps more importantly, more work is needed to link available ecological information to economic change; there is very little in the available literature that links the ecological system with the social system. A major confounding factor is the impact of other social and environmental changes, including cumulative impacts of large-scale development. There is no agreed-upon methodology to separate out the effects of climate change from cumulative impacts of development and other changes. Large unknowns at present include the understanding of the limits to adaptability in northern subsistence economies. Northern indigenous populations are better adapted to extreme events and annual, as well as seasonal, fluctuations as compared to non-indigenous groups. It is not clear whether acculturation has made these groups less vulnerable or more vulnerable to effects of climate change. A better understanding of the non-linear and discontinuous (unexpected) effects (Holling, 1986) of climate change on Arctic and Subarctic regions is needed, to help subsistence societies begin to anticipate and so begin to plan for unpredictable change, and to begin to assess the measure of risk they face.

Regarding the second point, research is needed to develop adaptive management strategies with the capacity not only to track changing conditions, but also to provide the flexibility to respond to uncertainty and environmental complexity in the context of rapid, and largely unpredictable, change (Holling, 1986). Adaptive management in this context refers to feedback learning, learning-by-doing and policies designed as experiments from which resource managers can learn. Fisheries management, for example, may have to manage both expanding and collapsing stocks, as climate change affects various stocks differently. Dramatic changes in the populations of mammals and birds will leave present management practices out of step with the changing environment. The implementation of effective adaptive management capacity will be a key factor influencing the extent to which the subsistence economy can be sustained in the years ahead.

Adaptive management is directly relevant to the maintenance and resilience of the social system as well. Increasing uncertainly implies that flexibility or keeping options open will become increasingly more important for long-term survival. One way of framing this issue is in terms of the resilience of the socio-economic system (Berkes and Folke, 1997); that is, the buffering capacity of the socio-economic system to absorb perturbations (such as impacts of climate change) and still retain its system characteristics. The ability of northern aboriginal groups to obtain their protein from their environment is perhaps one of the more important elements of such resilience of the socio-economic system because it encourages self-reliance.

A third area of study must address the issue of the health of northern populations. A direct link between the health of northern people and the extent to which they are able to enjoy a regular source of country food in their diet has not been proven. The ability to live at least partially off the land is not only important for socio-economic resilience; at a very practical level, it is important for individual nutritional health. Climate change has potentially significant implications for the long-term availability of this country food. As in the case of the Chisasibi Cree, rapid environmental change can make the local knowledge of the environment useless, and interfere with the ability to travel on and to harvest the land (Berkes, 1988). However, as in the case of hunters of the Nelson River, there is evidence of a high degree of adaptability even to massive change (Fast, 1996). The issue then is to know the limits to adaptability, and to make social and economic conditions conducive for the emergence of new adaptations. The issue may be generally applicable to rural populations elsewhere in Canada as well: there are costs associated with isolated populations becoming more and more dependent on the larger society for all their needs. There is no known basis which can be used to estimate the costs associated with increasing dependence, or, alternatively, the costs associated with the facilitation of potentially viable adaptations.

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